ČASOPIS
STUDIA OECOLOGICA
Ročník IX
Číslo 1/2015

Foto obálky
Mgr. Diana Holcová, Ph.D.

Vydává: FŽP UJEP v Ústí nad Labem

Toto číslo bylo dáno do tisku v prosinci 2015
ISSN 1802-212X
MK ČR E 17061

OBSAH

LOGISTIC CONCEPTION FOR REAL-TIME BASED INFO-COMMUNICATION SYSTEM APPLIED IN SELECTIVE WASTE COLLECTION

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Abstract

The decreasing number of the available raw materials, fossil energy sources and a new approach made recycling necessary and inevitable. For recycling selective waste areas have been placed where inhabitants can place their waste for free. Waste containers have different fill-up time since the collection process is predefined, therefore, independently whether it is needed or not they will be emptied. A further problem is that there is no optimisation on the way to the container, which results in serious environmental load (noise and air pollution). This study deals with high level route optimisation to minimize environmental load concerning noise and air pollution and by the application of real-time communication only the appropriate containers are going to be emptied.

Key words: *route optimisation, real-time system, measuring technique, info-communication, waste collection*

Introduction

Regarding environmental legislation, environmental load and recycling possibilities in Hungary, hundreds of settlements (even only with a few thousands of inhabitants) have established selective waste collection areas and placed various containers. Today the emptying process is based on empirical emptying value and in some cases the collection route is not optimised. In the EU there is a high pressure on waste collection companies in order to provide higher service standard for the same price. This can only be accomplished by a modern device which claims waste collection modelling (ABELIOTIS et al., 2009, OLIVEIRA et al., 2007, TAVARES et al., 2008). Studies exist all over the world presenting – Turkey (APAYDIN et al., 2007), India (GHOSE et al., 2006.), USA (SAHOO et al., 2005) – that fuel utilisation, collection route and time were decreased by software application fitted to local conditions – GIS 3D modelling, ArcGis®, és RouteViewPro™. The aim of this study is to introduce more ways of route optimisation based on container real-time communication.

Taking into account of the data coming from external systems to maximalise waste collection efficiency, the basic logistics procedure gradually elevates to a higher level using INPUT data.

Techniques applied today

In order to develop waste collection efficiency software and GPS service were applied for optimisation. Optimisation included fuel, route and collection time. Applying APAYDIN and GONULLU RouteViewPro™ software collection route is decreased by 24.6% and the time is decreased by 44.3% in Turkey. In the USA, in Illinois using WasteRoute software the study shows a 10% decrease in collection route (SAHOO et al., 2005).

Beside route optimisation further possibilities to decrease the number of collection round examinations also dealt with increasing waste collection vehicle capacity (GHOSE et al., 2006).

The waste transport processes were redesigned in Hungary by the Bay-Logi Research Centre on behalf of AVE Miskolc Ltd. applying RouteSmart software in order to decrease route and operational costs.

As a further domestic solution, the City of Győr being the owner of GYŐRSZOL Ltd. made emptying notification possible in case of filling up. The free call centre number can be read on the container side.

The introduced systems contribute to route optimisation, but so far there is no solution for indicating which container is full. The goal of this study is to develop an inverse logistic process applying an info-communication system to increase collection efficiency.

Real-time based info-communication system

The system is based on real-time info-communication and GIS technology (TITRIK, 2011). The new collection method has already been patented (P 1100734), which can be tested in a pilot project after operation and appropriate algorithm definition. Real tests can be carried out in Győr at GYŐRSZOL Ltd. There are three main system pillars: container fulfillment measurement, container information database, optimised emptying process and route definition. Real-time communication between containers and the route planning centre makes route redesigning possible to empty just full container(s) as well. Communication is also important in route planning regarding waste compression ratio since this can influence collection vehicle fill up time and position, therefore in case of not being full further containers can be emptied.

System operation

Elements of real-time based info-communication selective waste collection system (Figure 1):

1. selective waste container,
2. signal transmitter tower,
3. route planning centre,
4. waste collection vehicle.

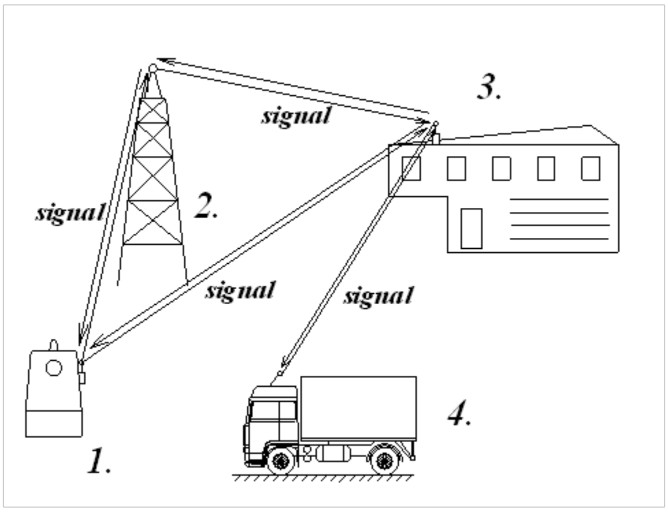

Fig. 1 Elements of real-time info-communication and signal flow

Design process of real-time based info-communication selective waste collection system optimisation

In order to enhance waste collection efficiency advantages of different vehicle types defined in logistics and organizing round trip the savings method was highlighted. This method is one of the well-known and oldest methods, of which algorithm has been still used mostly due to its simplicity and comprehensibility. Route planning software also contains this algorithm.

Certain parts of the optimisation process presented in the article can also be found in the work of A. Rovetta and et al. where advanced means of communication and measurement is applied to measure the weight and volume of the waste placed into the waste container. During the work related to research and development the container has been equipped with a GSM communicator and opening and closing the container the parameters of the waste are recorded in a visual form as well. The improvement aimed to optimise emptying order.

Due to the elements of real-time based info-communication selective waste collection system the inverse logistic process of waste collection reached a higher level. In case of having the required number of full containers the collection route planning is reasonable based on the following options:

1. Collection option

In terms of container emptying order optimisation.

Collection service basic data: no service for full containers, need for target service, only full containers are emptied (Figure 2).

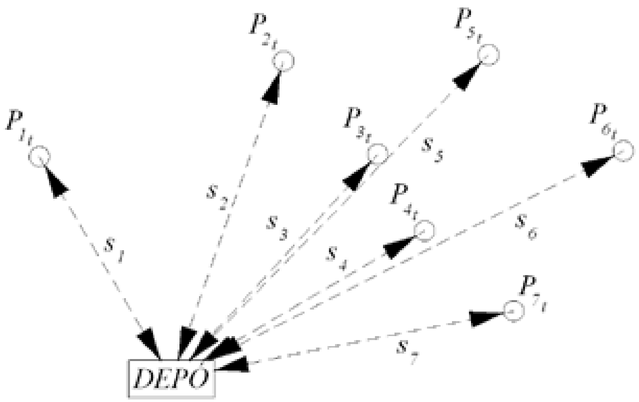

Fig. 2 Target service for collection

Collection characteristics:

$$Q_j >> \sum_{i=1}^{n=7} Q_{Pi},$$

where Q_j vehicle capacity and container Q_{Pi} capacity

$$2 * \sum_{i=1}^{n} s_i >> s_1 + s_n + \sum_{i=1}^{n=6} s_{i,i+1},$$

where s_i route between each container and DEPOT.

Analysing collection option 1:

Collection is characterised as the simplest collection form in logistics – the target places are visited by the vehicle and the material placed into the containers is delivered to the depot separately. Concerning waste collection, this method is valid only in case of 3-21 m^3 containers being delivered without a trailer. It is also characterised by the fact that the access route with the collection points will not get optimised without a proper plan. On the basis of the volume of the placed containers – in general of 1,5m^3 or 2,5m^3 – and their number – 1 or 2 containers are usual collecting one type of waste, the emptying of the containers - due to the huge capacity of the collection vehicle – can be carried out safely. Since the vehicle is not filled up in this case, its capacity utilisation is far lower than the optimal.

Features of collection method:

- most simple collection method,
- safe emptying due to waste volume and known vehicle capacity,
- optimised container emptying order,
- not optimised collection method,
- not optimised vehicle capacity,
- not optimised route to containers.

2. Collection option

In terms of optimised route to containers.

Collection service basic data: savings method for full containers, only full containers are emptied (Figure 3).

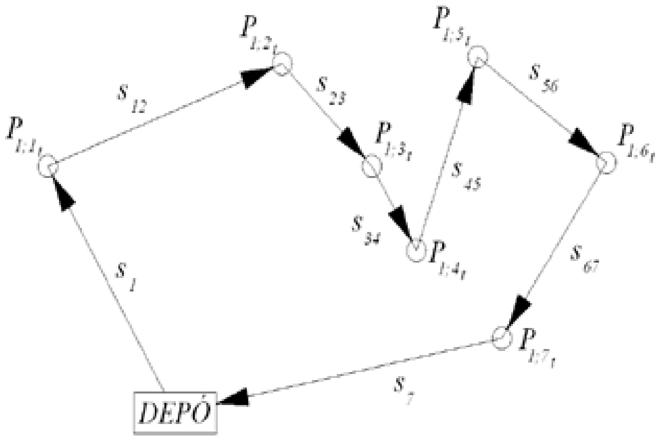

Fig. 3 Savings method for waste collection

The following equation must be valid for collection process:

$$Q_j \geq \sum_{i=1}^{n=7} Q_{Pi},$$

where Q_j vehicle capacity and Q_{Pi} container capacity

Analysing the 2nd collection option:

It is the improvement of the 1st collection option. The access route to the various full containers got optimised. In this case the method of savings algorithm was used which means that the containers are collected one after the other and the vehicle returns to the depot only at the end of the collection round. In this case the collection method is not optimised because they failed to take into consideration how full the vehicle was and it is impossible to judge whether the vehicle has some spare capacity during the collection process or it would reach its full capacity in which case a further round would be necessary to collect the remaining refuse. Further optimisation is necessary based on the vehicle's capacity utilisation.

Features of collection method:

- optimised route to containers,
- uncertain emptying due to waste compression and further compression ratio – volume-mass ratio,
- optimised container emptying order,
- not optimised collection method,
- not optimised vehicle capacity.

3. Collection planning

In terms of vehicle capacity.

Collection service basic data: savings method for full containers, only full containers are emptied, vehicle fill-level considered (Figure 4).

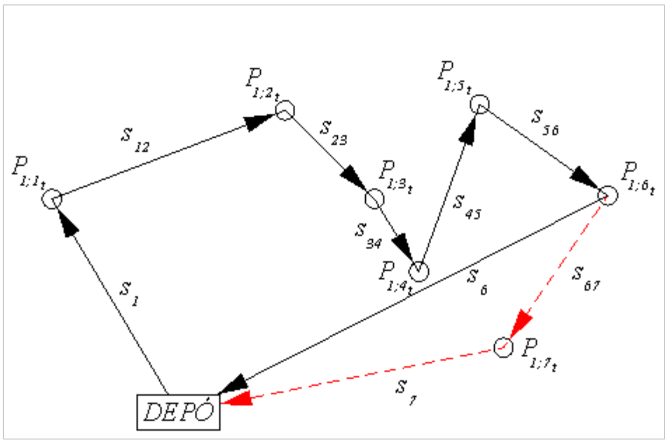

Fig. 4 Vehicle fill-level considered

$$Q_j < \sum_{i=1}^{n=7} Q_{Pi},$$

where Q_j vehicle capacity and Q_{Pi} container capacity

$P_{1;7_t}$ container not emptied because of the fill-level of the vehicle, so the route marked with red colour is not completed by the vehicle

Characteristics of collection method:

$$s_{össz} = (s_1 + s_6 + \left(\sum_{i=1}^{n=5} s_{i;i+1}\right)) + 2 * s_7,$$

$$Q_1 >> Q_2 \text{ and } Q_1 \cong Q_j \text{ and } Q_2 << Q_j,$$

where Q_j vehicle capacity and Q_i collection round capacity

Analysing the 3rd collection option:

It is a further analysis of the previous collection option taking vehicle capacity as a primary factor into account. This collection option determines if the containers should be emptied into the vehicle or not and the optimised access route.

Features of collection method:

- optimised route to containers,
- safe emptying due to known waste volume-mass ratio,
- optimised container emptying order,
- not optimised collection method,
- not optimised vehicle capacity.

4. Collection planning

In terms of route redefinition due to vehicle capacity.

Collection service basic data: savings method for full containers, only full containers are emptied, vehicle fill level considered, optimised collection method (Figure 5).

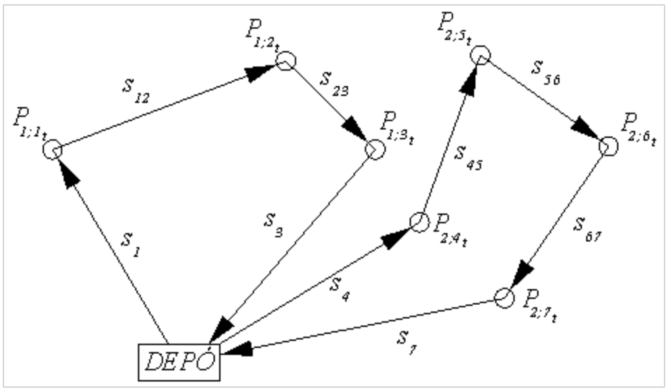

Fig. 5 Route optimisation in consideration of vehicle capacity

Characteristics of collection method:

$$Q_{ji} >> Q_i,$$

where Q_j vehicle capacity and Q_i containers in a collection round

$$S_1 = (s_1 + s_3 + \left(\sum_{i=1}^{n=2} s_{i;i+1}\right)),$$

$$S_2 = (s_4 + s_7 + \left(\sum_{i=4}^{n=6} s_{i;i+1}\right)),$$

$$S_{össz} = S_1 + S_2,$$

$$Q_1 \cong Q_2 \text{ and } Q_1 << Q_j \text{ and } Q_2 << Q_j$$

where Q_j vehicle capacity and Q_i collection round capacity

Analysing the 4th collection option:

Taking into account the capacity of the vehicle, the access route got divided into two phases because of the overloaded state of the collection vehicle. The containers on the routes can be emptied safely. In this particular case the capacity utilisation of the vehicle was repeatedly not optimised, so further containers need to be added to the emptying process.

Features of collection method:

- optimised route to containers,
- safe emptying due to known waste volume-mass ratio,
- optimised container emptying order,
- not optimised collection method,
- not optimised vehicle capacity.

5. Collection planning

In terms of optimised vehicle fill-level.

Collection service basic data: savings method for full containers, beside full containers not saturated ones are also collected, vehicle fill-level considered, optimised collection method (Figure 6).

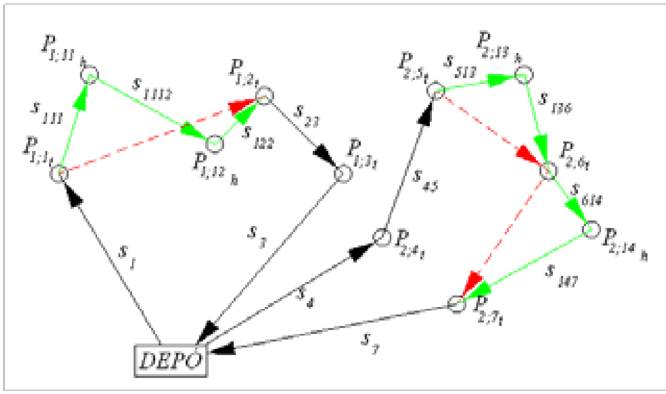

Fig. 6 Further containers are emptied due to vehicle fill-level optimisation

Characteristics of collection method:

$$Q_{ji} \geq Q_i,$$

where Q_j vehicle capacity and Q_i containers in a collection round and $P_{.;.h}$-not filled up containers

due to content level optimisation of the vehicle on the route marked with black colour, the vehicle goes on the green route to pick up further containers instead of the original route (red)

Analysing the 5th collection option:

The 5th collection option was created to determine capacity utilisation. Further nearby containers are added to the emptying routine of the containers with full content. It is essential to select the most easily available and the closest containers. This method ensures the enhancement of the capacity utilisation of the vehicle.

Features of collection method:

- safe emptying due to known waste volume-mass ratio,
- optimised container emptying order,
- optimised collection method,
- optimised vehicle capacity,
- optimised route to containers.

6. Collection planning

In terms of saturation trend considered containers expected to be saturated are also collected.

Collection service basic data: savings method for full containers, beside full containers, not filled up ones are also collected, due to trend expected container saturation also considered in collection route planning, vehicle fill-level considered, optimised collection method (Figure 7).

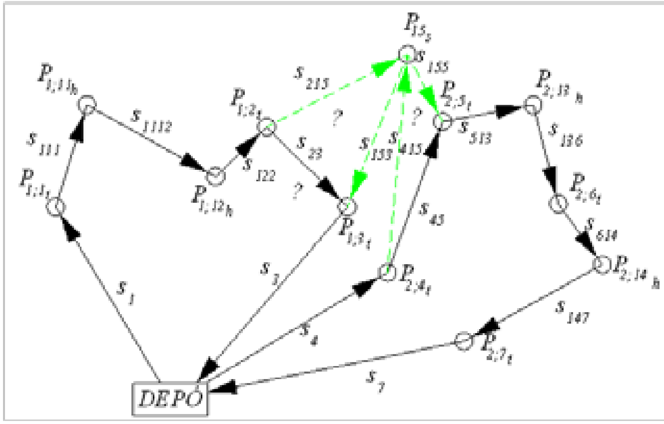

Fig. 7 Expected container fill up considered in collection

Characteristics of collection method:

$$Q_{ji} \geq Q_{i},$$

where Q_j vehicle capacity and Q_i containers in a collection round

$$\min((s_{215} + s_{153}) - s_{23}; (s_{415} + s_{155}) - s_{45}),$$

and $P_{.;.s}$ - on the basis of statistical data the container is going to be filled up in a short time applying further containers soon filled up requires optimisation regarding in which round the vehicle empties them

Analysing the 6th collection option:

The 6th collection option describes the method of collecting those containers on the route which are still not filled up but taking into account their filling-up routine their fill-ups are expected in a short time. It is essential that the most easily accessible, the closest and most justified containers should be emptied among the ones still not filled up to the brim.

Features of collection method:

- safe emptying due to known waste volume-mass ratio,
- optimised container emptying order,
- optimised collection method,
- optimised vehicle capacity,
- optimised route to containers.

7. Collection planning

In terms of defined route plan is redesigned during the collection process due to just filled up containers.

Collection service basic data: savings method for full containers, beside full containers, not full ones are also collected, due to trend expected container saturation also considered in collection route planning, just saturated containers considered in collection round, vehicle saturation considered, optimised collection method (Figure 8).

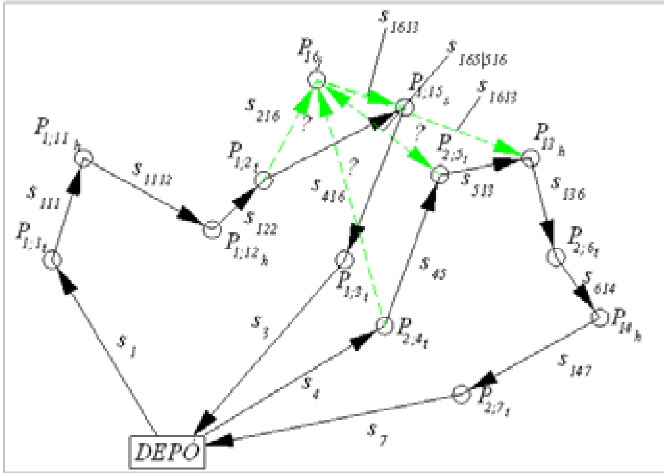

Fig. 8 Further full containers in collection round

Characteristics of collection method:

$$Q_j \geq \min\left(\sum_{i=1}^{n=3} Q_{Pi} + \sum_{i=11}^{n=12} Q_{Pi} + P_{15} + P_{16_j} ; \sum_{i=4}^{n=7} Q_{Pi} + \sum_{i=13}^{n=14} Q_{Pi} + P_{16_j}\right)$$

where Q_j vehicle capacity and Q_i containers in a collection round
and $P_{.;j}$- full containers during collection

P_{16_j} container got filled up during collecting containers, so applying capacity analysis and optimisation is needed to determine whether it is possible to empty it and which vehicle should empty it.

Analysis of the 7th collection option:

In the case of the 7th collection option the predetermined route is redesigned due to new full containers near the regular route of the vehicle. In this case analysing capacity and selecting in which round the full container should be emptied are required. Due to the vehicle's capacity problem and priority issues, the full container is given preference to the not full container. It is important to emphasise the analysis of the length of the route, as the redesigned route cannot be longer than the distance between the filled up container and the depot twice.

Features of collection method:

- safe emptying due to known waste volume-mass ratio and vehicle optimisation needed due to further just-in-time container fill-level notification,
- optimised container emptying order,
- optimised collection method,
- optimised vehicle capacity,
- optimised route to containers.

8. Collection planning

In terms of communication with other operators – public road maintenance, public place maintainer – route is redesigned.

Collection service basic data: savings method for full containers, beside full containers, not full ones are also collected, due to trend expected container saturation also considered in collection route planning, just saturated containers considered in collection round, vehicle saturation considered, optimised collection method, defined route validation due to occasional road maintenance (Figure 9).

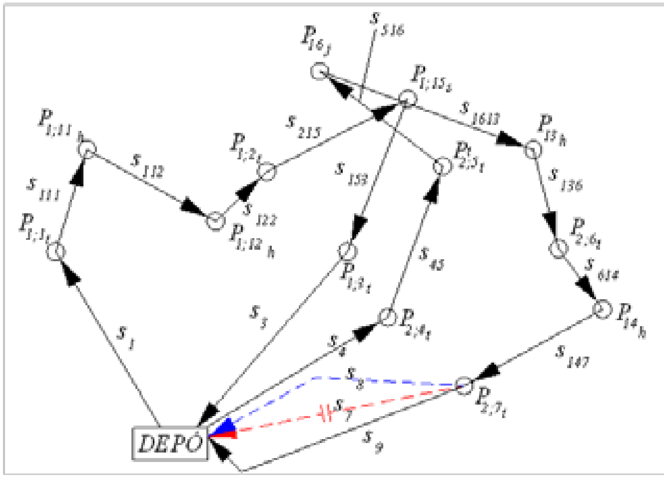

Fig. 9 Route modification in consideration of other operators' data

Characteristics of collection method:

$$s_8 \geq s_9$$

based on INPUT data the original route (red) cannot be used, so other access routes need to be found – among which the one marked with black is (s_9) the appropriate

Analysing the 8th collection option:

The 8th collection option controls whether the defined route is achievable or not. It is not uncommon that some road sections are closed or temporary one-way traffic is introduced on them for the time of road maintenance – road or utility improvements carried out by other public services. Involving further public services, an online system allows to easily detect these types of interventions concerning waste collection. This intervention is recognised as INPUT data by the optimisation software and starts a search for a new access route.

Features of collection method:

- safe emptying due to known waste volume-mass ratio and vehicle optimisation needed due to further just-in-time container saturation notification,
- optimised container emptying order,
- optimised collection method,
- optimised vehicle capacity,
- optimised route to containers.

Each option and their extensions make a simple logistic task develop to a high-level collection process. The different approaches applying statistical data, further operators, vehicle capacity level and more instruments take part in all processes of waste collection not only in one specific task. In Table 1 the advantages of each collection method can be seen, while Table 2 includes terms of each collection method.

Table 1: Applied advantages in each collection process

	Advantages				
	optimised route	**emptying the container is feasible**	**optimised collection method**	**optimised vehicle capacity utilization**	**optimised emptying order**
1. collection option		X			
2. collection option	X				X
3. collection option	X	X			X
4. collection option	X	X			X
5. collection option	X	X	X	X	X
6. collection option	X	X	XX	X	X
7. collection option	X	X	XXX	X	X
8. collection option	XX	X	XXX	X	X

(more X = higher level)

Table 2: Terms/considered tasks/goals in each collection process

	Terms/considered tasks/goals
1. collection option	optimised emptying order
2. collection option	container route optimisation
3. collection option	vehicle capacity considered
4. collection option	redefined route due to vehicle capacity
5. collection option	optimised vehicle saturation
6. collection option	saturation trend considered containers expected to be saturated are also gathered
7. collection option	defined route plan is redefined during collection process due to just saturated containers
8. collection option	communication with other operators – public road maintenance, public place maintainer – route is redefined

Analysing the steps of the previously described optimisation process, its positive features on the process of waste collection applying the system can be stated. To maximise collection efficiency, introducing a new system is not enough, it is also important to be able to adjust it to further systems articulating a higher level collection process with ensuring data exchange.

Summary

Doing Research-Development a new optimising system got defined which determines not just the optimal emptying routine, but the entire procedure of collection. The system upgrades a basic collection method into a higher level applying various INPUT elements such as capacity analysis, statistical data, etc.

More liveable cities can be organized by applying real-time based info-communication system in waste collection since reasonable emptying processes are accomplished in time, while not required collection tasks are left out. Environmental load can be decreased and traffic safety can be increased significantly by different external communication influencing route definition – not required collection tasks are left out, optimised collection vehicle capacity utilization, road maintenance also considered necessarily modifying predefined route, optimised collection route length.

Further measurements, investigations and simulation scientific investigations - in connection with the research - will be introduced in the forthcoming series of articles.

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PUBLISHING RULES OF THE STUDIA OECOLOGICA SCIENTIFIC JOURNAL

1. The Studia Oecologica Scientific Journal (hereinafter referred to as "Journal") is published twice a year, generally in spring and autumn. It is possible to include more issues, dealing with specific topics, e.g. significant projects solved within the scope of the Faculty of Environment, during the year.

2. The Journal is published in a printed version; simultaneously it is available on the faculty´s websites.

3. The published papers focus on questions related to ecology and environmental conservation and protection. The major types of papers are following:
   a) original scientific essays resulting from research work,
   b) scientific overview articles (reviews),
   c) summaries of post-gradual and inaugural dissertations as well as the best bachelor and master theses which were defended on the faculty,
   d) chronicle, information on significant conferences, publications etc.

4. The publication in the Journal is destined in particular to academic workers of the Faculty of Environment as well as of other faculties of J. E. Purkyně University. Papers of other specialists from the ecologic and environmental protection area as well as environmentally oriented places of work, students included, are accepted, too.

5. The author answers for the originality, scientific and formal correctness of the paper. It is not possible to publish articles which have been already published in another journal; the author confirms this by the cover letter, which contains the information that the paper is destined to be published in the Studia Oecologica Scientific Journal. The letter also includes data on the author, who is responsible for communication with the Journal redaction, and suggestion of at least one reviewer, who corresponds to the criteria mentioned below. Paper handover shows that the author is acquainted with the publishing terms and he agrees with paper publication following these terms. The author must also observe the below mentioned ethical principles of publishing.

6. The authors are required to follow the principles of scientific, artistic and another creative work that are set in the ethics code of academic workers. These are especially principles of objectivity, plagiarism and result fragmentation avoidance and dividing the results into several publications.

7. The manuscripts are accepted by the Officer of the publishing activities of the Faculty of Environment during the whole calendar year. The editor´s office address is: J. E. Purkyně University, the Faculty of Environment, the Officer of the publishing activities, Králova Výšina 3132/7, 400 96 Ústí nad Labem.

8. The text part of the manuscript must be written in MS Word and it is usually handed over as an electronic file, graphical documentation and appendix of figures included. The clean copy must agree with the instructions mentioned on the faculty´s websites, in the "Studia Oecologica" section, and in particular Journal issues.

9. The papers are published in Czech, Slovak, English and German. Those which are published in Czech and Slovak language must contain English or German abstract.

10. Papers intended to reviewer proceedings are chosen by the Journal Editorial Council that reserves the right to refuse the papers, which do not correspond to the above mentioned principles or have an inappropriate formal level.

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